Appendix A

# Harmonia$^{+PL}$ – procedure for negative impact risk assessment for invasive alien species and potentially invasive alien species in Poland

## QUESTIONNAIRE

## A0 | Context

Questions from this module identify the assessor and the biological, geographical & social context of the assessment.

**a01**. Name(s) of the assessor(s):

first name and family name

1. Anna Maria Łabęcka – external expert
2. Aneta Spyra
3. Małgorzata Strzelec

acomm01. Comments:

| | degree | affiliation | assessment date |
|---|---|---|---|
| (1) | dr | Institute of Environmental Sciences, Faculty of Biology, Jagiellonian University in Cracow | 31-01-2018 |
| (2) | dr | Department of Hydrobiology, Faculty of Biology and Environmental Protection, University of Silesia | 31-01-2018 |
| (3) | prof. dr hab. | Department of Hydrobiology, Faculty of Biology and Environmental Protection, University of Silesia | 01-02-2018 |

**a02**. Name(s) of ***the species*** under assessment:

Polish name: –

Latin name: ***Corbicula fluminea*** (O.F. Müller, 1774)

English name: Asian clam

Współfinansowano w ramach projektu nr POIS.02.04.00-00-0100/16 pn. *Opracowanie zasad kontroli i zwalczania inwazyjnych gatunków obcych wraz z przeprowadzeniem pilotażowych działań i edukacją społeczną* ze środków Unii Europejskiej w ramach Programu Infrastruktura i Środowisko 2014-2020

acomm02. Comments:

Polish name: none.

Synonyms according to: Stańczykowska and Kołodziejczyk 2011 - P, GISD 2015 -B

| Polish name (synonym I) | Polish name (synonym II) |
|---|---|
| – | – |
| **Latin name (synonym I)** | **Latin name (synonym II)** |
| *Corbicula leana* | – |
| **English name (synonym I)** | **English name (synonym II)** |
| Asiatic clam | – |

**a03**. **Area** under assessment:

**Poland**

acomm03. Comments:

–

**a04**. **Status** of *the species* in Poland. *The species* is:

| | |
|---|---|
| | native to Poland |
| | alien, absent from Poland |
| | alien, present in Poland only in cultivation or captivity |
| | alien, present in Poland in the environment, not established |
| **X** | alien, present in Poland in the environment, established |

aconf01. Answer provided with a

| low | medium | high |
|---|---|---|
| | **X** | |

level of confidence

acomm04. Comments:

*Corbicula fluminea* is spreading in Poland. It probably reached the waters of our country from the west of Europe as a plankton larva together with fry brought to fish farms. It could have been thrown by anglers as a bait or got in a juvenile form (on bird legs and feathers) (Domagała et al. 2004 - P). At the moment, the species is recorded in the two largest Polish rivers: Oder River and Vistula River (Domagała et al. 2004, Wawrzyniak - Wydrowska 2007, Maćkiewicz 2013, Piechocki and Szlauer-Łukaszewska 2013, Romanowski et al. 2016, Cebulska i Krodkiewska 2017, Bonk et al. 2018 - P). This clam occurs on various sections of the Oder River from its source to its mouth (Wawrzyniak-Wydrowska 2007 - P), including in the Szczecin Lagoon (Marchowski et al. 2016 - P). In Vistula River, the species is present in the upper reaches of the river from Opatowiec to Warsaw; unfortunately there is no data for the middle and lower section of the Vistula River (Maćkiewicz 2013, Romanowski et al. 2016, Bonk et al. 2018 - P). *Corbicula fluminea* reproduces in warm cooling waters at the "Dolna Odra" power plant throughout the year (Łabęcka 2009 - P). There is no data on reproduction for other sites of this species in Poland.

**a05**. The impact of *the species* on major domains. *The species* may have an impact on:

| | |
|---|---|
| **X** | the environmental domain |
| | the cultivated plants domain |
| | the domesticated animals domain |
| **X** | the human domain |
| **X** | the other domains |

acomm05. Comments:

*Corbicula fluminea*, according to research conducted in other countries, reduces the availability of habitats, competes with native species of bivalves for food and space, contributing to their displacement (Vaughn and Hakenkamp 2001, Pérez-Bote and Fernández 2008 - P). This clam transforms (by drilling in the bottom sediment) the surface

of the bottom of the water reservoir (Vaughn and Hakenkamp 2001 - P), releases a large amount of inorganic nitrogen in the form of feces and pseudofeces (Asmus and Asmus 1991 - P), it can accumulate heavy metals and pesticides (Villar et al. 1999, Uno et al. 2001 - P), affects water quality (Strayer 1999 - P).

Clam tissues secrete mucus which can be allergenic for some people as a result of direct contact (BHP UJ 2010 - I).

In Poland, no harmful effect of *C. fluminea* on hydrotechnical devices has been demonstrated, yet in the USA, Belgium and France, this clam poses a threat to the operation of submerged devices, including waterworks (Lachner et al. 1970, Swinnen et al. 1998 - P). *Corbicula fluminea* shells can also pose a problem for companies trading in sand and river gravel – these raw materials are contaminated with clam shells (Darrigran 2002 - P).

The impact of the species on the basic spheres was described in detail in questions a13-a18, a28-a29, a30-a33.

## A1 | Introduction

Questions from this module assess the risk for *the species* to overcome geographical barriers and – if applicable – subsequent barriers of captivity or cultivation. This leads to *introduction*, defined as the entry of *the organism* to within the limits of *the area* and subsequently into the wild.

**a06**. The probability for ***the species*** to expand into Poland's natural environments, **as a result of self-propelled expansion** after its earlier introduction outside of the Polish territory is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

aconf02. Answer provided with a

| low | medium | high | level of confidence |
|---|---|---|---|
| | | **X** | |

acomm06. Comments:

The species is already present in Poland. Living individuals were located in 2003 in the "Dolna Odra" power plant near Nowe Czarnowo (West Pomeranian Voivodeship) (Domagała et al. 2004 - P), but empty shells of these clams were already observed in the Oder River near the Dziewoklicz swimming area near Szczecin before (Piechocki - oral information 2004 - I). *Corbicula fluminea* occurs in numerous sites in Europe, including water environments of countries neighboring Poland (Germany, Czech Republic, Slovakia) (Tittizer and Taxacher 1997, Beran 2000, Vrabec et al. 2003 - P). Outside Poland, the species is described as rapidly spreading. It seems that the risk of its spreading spontaneously with river waters is quite high, but not always possible due to the effect of various environmental factors, e.g. low temperatures.

**a07**. The probability for *the species* to be introduced into Poland's natural environments by **unintentional human actions** is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

aconf03. Answer provided with a

| low | medium | high | level of confidence |
|---|---|---|---|
| | | **X** | |

acomm07. Comments:

The species is already present in Poland. The way of introducing *C. fluminea* to Polish inland waters is unknown. It is assumed that it was introduced as a plankton larva present in water, in which fish were transported to local farms (Domagała et al. 2004 - P). They also

| | |
|---|---|
| | take into account the possibility of transporting this species on barges carrying river gravel (gravel ensures adequate humidity) (Lachner et al. 1970 - P), the risk of introducing *C. fluminea* into the natural environment due to unintended human activities is high. |

**a08**. The probability for *the species* to be introduced into Poland's natural environments by **intentional human actions** is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf04. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm08. Comments:

The species is already present in Poland. It can probably be introduced into the natural environment by tourists, aquarists or anglers (Lachner et al. 1970 - P). Large sales of this clam were recorded in Poland in 2004-2010 under the trade name "*Corbicula javanicus*", both on the Allegro Internet portal and in online aquarist shops (Łabęcka 2004-2010 - A). This process continues to this day (Allegro 2018 - I).

## A2 | Establishment

Questions from this module assess the likelihood for *the species* to overcome survival and reproduction barriers. This leads to *establishment*, defined as the growth of a population to sufficient levels such that natural extinction within *the area* becomes highly unlikely.

**a09**. Poland provides **climate** that is:

| | |
|---|---|
| | non-optimal |
| | sub-optimal |
| **X** | optimal for establishment of *the species* |

| | | | | | |
|---|---|---|---|---|---|
| aconf05. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm09. Comments:

*Corbicula fluminea* is an aquatic animal. The temperature tolerance range for this species is from 2 to 34°C (Mattice and Dye 1976, McMahon 1983 - P). Clams are also able to survive at the temperature of 0°C, but such a low water temperature combined with its low state (level) may be a factor limiting their presence (Werner and Rothhaupt 2008, Müller and Baur 2011 - P). *Corbicula fluminea* is sensitive to water temperatures above 36°C, and to lack of oxygen (Illari et al. 2011, Johnson and McMahon 2011 - P). Assemblages of these clams are recorded in both the Oder and Vistula Rivers (Piechocki and Szlauer-Łukaszewska 2013, Cebulska-Krodkiewska 2017, Bonk et al. 2018 - P), but it may be assumed that formation of new populations or "renewal" of clam assemblages after a more severe winter may occur as a result of colonization with larvae produced within the warm cooling waters. This could be indicated by the comparison between the size of clam shells in different sections of the Vistula River depending on the distance from the power plant (the further downstream of the power plant, the smaller the sizes of *C. fluminea* shells were noted (Bonk et al. 2018 - P)). The species is capable of surviving winter periods in Polish waters, yet there is no evidence confirming that *C. fluminea* can reproduce outside warm cooling waters. Because of that, it seems that the climatic conditions in Poland cannot be considered optimal for the establishment of this species.

Methodology of Harmonia + PL The procedure for negative impact risk assessment for invasive alien species and potentially invasive alien species in Poland (hereinafter Harmonia$^{+PL}$) indicates to select answer: optimal conditions, with a high level of confidence.

**a10**. Poland provides **habitat** that is

| | |
|---|---|
| | non-optimal |
| | sub-optimal |
| **X** | optimal for establishment of *the species* |

| | | | | | |
|---|---|---|---|---|---|
| aconf06. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm10. Comments:

*Corbicula fuminea* inhabits various aquatic environments in Europe (Sousa et al. 2008 a, Ciutti and Cappelletti 2009, Schmidlin et al. 2012 - P): rivers (Elliott and Ermgassen 2008 - P), lakes (Hubenov et al. 2013 - P), canals and ponds (Aldridge and Müller 2001 - P), estuaries (Ferreira-Rodríguez and Pardo 2016 - P). It prefers sandy, gravel and mud bottoms; it avoids bottoms covered with organic sediment (Stańczykowska and Kołodziejczyk 2011 - P). In Poland, it is present in the Oder and the Vistula Rivers (freshwater reservoirs) and in the Szczecin Lagoon (with brackish waters) (Domagała et al. 2004, Wawrzyniak-Wydrowska 2007, Maćkiewicz 2013, Piechocki and Szlauer-Łukaszewska 2013, Marchowski et al. 2016, Romanowski et al. 2016, Cebulska and Krodkiewska 2017, Bonk et al. 2018 - P). It achieves density of 28-93 individuals/$m^2$ in the cooling waters of the "Dolna Odra" power plant (Łabęcka 2005-2007 - A) and 142-6694 individuals/$m^2$ in various sections of the Vistula River, including the highest ones in the heated waters released by the "Połaniec" power plant (Bonk et al. 2018 - P). In Portugal, in the south of Europe, its density is extremely different (e.g. from 80 to 4185 individuals/$m^2$), but it is not related to the water temperature (Sousa et al. 2008 a, b - P). The increase in biomass and achievement of higher densities in *C. fluminea* are favored by higher values of oxidation-reduction potential, water hardness and organic matter content (Vaughn and Hakenkamp 2001, Sousa et al. 2008 a, b- P). Weaker water flow and oxygen content decrease can cause mass mortality of the clams. In Poland, due to the availability of habitats inhabited by specimens of this species, these conditions should be described as optimal for establishment.

## A3 | Spread

Questions from this module assess the risk of *the species* to overcoming dispersal barriers and (new) environmental barriers within Poland. This would lead to spread, in which vacant patches of suitable habitat become increasingly occupied from (an) already-established population(s) within Poland.

Note that spread is considered to be different from range expansions that stem from new introductions (covered by the Introduction module).

**a11**. The capacity of *the species* to disperse within Poland by natural means, **with no human assistance**, is:

| | |
|---|---|
| | very low |
| | low |
| | medium |
| | high |
| **X** | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf07. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm11. Comments:

Dispersion from a single source (Data type: A) (over 50 km per year). No data for Poland. According to Bij de Vaate (1991 - P) *C. fluminea* can "cover" up to 100 km a year, which is assessed as a very large dispersibility. *Corbicula fluminea* larvae and juveniles of this species are passively transported with the water current. In addition, they can also be carried on bird legs or feathers (Prezant and Chalermat, 1984, McMahon 2000, 2002 - P). It is likely that even fish may be responsible for the dispersion of this species (Cantanhede et al. 2008

| | |
|---|---|
| | - P). Beyond the borders of our country, the ability of this species to spread spontaneously is described as very large (Minchin 2014 - P). |

**a12**. The frequency of the dispersal of *the species* within Poland by **human actions** is:

| | |
|---|---|
| | low |
| **X** | medium |
| | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf08. | Answer provided with a | low<br>**X** | medium | high | level of confidence |

| | |
|---|---|
| acomm12. | Comments:<br>The species is found in a few sites in Poland, however, the number of sites increases with the extent of studying watercourses constituting possible ways of *C. fluminea* expansion. There are no reports of this clam spread with human involvement in Poland. With a low level of confidence, it is estimated that this frequency could be medium – no more than 10 expected cases of such spread per decade, e.g. with the participation of anglers (who could use these clams as bait) or through tourist and aquarist carelessness. |

## A4a | Impact on the environmental domain

Questions from this module qualify the consequences of *the species* on wild animals and plants, habitats and ecosystems.

Impacts are linked to the conservation concern of targets. Native species that are of conservation concern refer to keystone species, protected and/or threatened species. See, for example, Red Lists, protected species lists, or Annex II of the 92/43/EWG Directive. Ecosystems that are of conservation concern refer to natural systems that are the habitat of many threatened species. These include natural forests, dry grasslands, natural rock outcrops, sand dunes, heathlands, peat bogs, marshes, rivers & ponds that have natural banks, and estuaries (Annex I of the 92/43/EWG Directive).

Native species population declines are considered at a local scale: limited decline is considered as a (mere) drop in numbers; severe decline is considered as (near) extinction. Similarly, limited ecosystem change is considered as transient and easily reversible; severe change is considered as persistent and hardly reversible.

**a13**. The effect of *the species* on native species, through **predation, parasitism or herbivory is**:

| | |
|---|---|
| | inapplicable |
| **X** | low |
| | medium |
| | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf09. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm13. | Comments:<br>*Corbicula fluminea* does not affect native species through predation, parasitism or herbivory. This species is a filter feeder, and its diet may include phytoplankton. |

**a14**. The effect of *the species* on native species, through **competition** is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf10. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm14. Comments:

No data available for Poland, yet based on American studies (in the USA this clam has been observed since 1924) we know that *C. fluminea* reduces the availability of habitats and contributes to the displacement of native bivalve species. Small pill clams and fingernail clams, as well as young *Unionidae* individuals are particularly vulnerable (Vaughn and Hakenkamp 2001 - P). *Corbicula fluminea* is described as a species competing with native bivalves for food and space (Pérez-Bote and Fernández 2008 - P), as well as other species living on the bottom of reservoirs (it limits food access for plankton feeders). It can also filter *Unionidae* mussel spermatozoa, their glochidia and even young individuals just after metamorphosis (McMahon 1991, Strayer 1999 - P). Thus, it can contribute to the effective "elimination" of the new generation of these mussels. The analysis of food content in *C. fluminea* demonstrated lack of selectivity in nutrition (Boltovskoy 1995 - P), which at high densities can mean a high impact of this species on the availability of food for native fauna. Assuming that the species will be established all over Poland, it will be able to cause serious decreases in the population size of native special care species (e.g. bivalves).

**a15**. The effect of *the species* on native species, through **interbreeding** is:

| | |
|---|---|
| **X** | no / very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf11. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm15. Comments:

*Corbicula fluminea* does not interbreed with native bivalve species, but it can form hybrids with *C. fluminalis*–a non-native species for the fauna of Europe (Pfenniger et al. 2002 - P).

**a16**. The effect of *the species* on native species by **hosting pathogens or parasites** that are harmful to them is:

| | |
|---|---|
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf12. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm16. Comments:

No internal parasites harmful to native species were found in *Corbicula fluminea* (Łabęcka 2009 - P).

**a17**. The effect of *the species* on ecosystem integrity, by **affecting its abiotic properties** is:

| | |
|---|---|
| **X** | low |
| | medium |
| | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf13. | Answer provided with a | low | medium **X** | high | level of confidence |

| | |
|---|---|
| acomm17. | Comments:<br>There is no data for Poland, but on the basis of other researches, this clam transforms (by drilling in the bottom sediment) the surface of the bottom of the water reservoir (Vaughn and Hakenkamp 2001 - P). *Corbicula fluminea* can also release a large amount of inorganic nitrogen in the form of feces and pseudofeces (Asmus and Asmus 1991 - P). Mass mortality of clams affects water quality (Strayer 1999 - P). The introduction of the species may have effect on the carbon and nutrient cycling in river ecosystems (Hakenkamp and Palmer 1999 - P). In Poland, there were small densities of this species (see a10, acomm10) compared to the countries in the south of Europe, therefore the effect of the species on the integrity of the ecosystem by disrupting its abiotic factors was rated as "low". Even assuming that the species, e.g. as a result of global warming, would become widely distributed in Poland and numerous, worst case scenario it can cause easily reversible changes in processes occurring in habitats that do not belong to special care habitats (such as various types of anthropogenic reservoirs outside protected areas or included in the Natura 2000 network). |

**a18**. The effect of *the species* on ecosystem integrity, by **affecting its biotic properties** is:

| | |
|---|---|
| | low |
| **X** | medium |
| | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf14. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm18. | Comments:<br>There is no data for Poland, but based on other studies, this clam reduces the availability of habitats and can displace native bivalve species (Vaughn and Hakenkamp 2001 - P). It competes for food with other filter feeders and can also remove other larvae from the water column (McMahon 1991, Strayer 1999 - P). High mortality of the population can affect the biotic components of the environment and water quality (Sousa et al. 2007, Sousa et al. 2008 a, b - P). The presence of the species stimulates the fungal biomass and the diversity of bacteria which affects the functioning of aquatic ecosystems (Novais et al. 2016 - P). Small densities of this species have been recorded in Poland (cf a10, acomm10) in comparison to countries in the south of Europe, therefore the current effect regarding the disturbance of biotic relations should be assessed as low. Nevertheless, assuming that the species would become widespread and numerous in Poland, its potential effect should be assessed as medium. In this situation, worst case scenario, the species could cause hardly reversible changes in processes occurring in habitats that do not belong to special care habitats or easily reversible changes in the special care habitats. |

## A4b | Impact on the cultivated plants domain

Questions from this module qualify the consequences of *the species* for cultivated plants (e.g. crops, pastures, horticultural stock).

For the questions from this module, consequence is considered 'low' when presence of *the species* in (or on) a population of target plants is sporadic and/or causes little damage. Harm is considered 'medium' when *the organism's* development causes local yield (or plant) losses below 20%, and 'high' when losses range >20%.

**a19**. The effect of *the species* on cultivated plant targets through **herbivory or parasitism** is:

| | |
|---|---|
| | inapplicable |
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf15. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm19. Comments:

*Corbicula fluminea* is a clam - a water animal, a filter feeder. It feeds on plankton, therefore it does not affect plant cultivation through herbivorousness or parasitism.

**a20**. The effect of *the species* on cultivated plant targets through **competition** is:

- **X** inapplicable
- ☐ very low
- ☐ low
- ☐ medium
- ☐ high
- ☐ very high

| | | | | | |
|---|---|---|---|---|---|
| aconf16. | Answer provided with a | low | medium | high | level of confidence |

acomm20. Comments:

Not applicable. Clams are water animals.

**a21**. The effect of *the species* on cultivated plant targets through **interbreeding** with related species, including the plants themselves is:

- **X** inapplicable
- ☐ no / very low
- ☐ low
- ☐ medium
- ☐ high
- ☐ very high

| | | | | | |
|---|---|---|---|---|---|
| aconf17. | Answer provided with a | low | medium | high | level of confidence |

acomm21. Comments:

Not applicable. Clams are animals.

**a22**. The effect of *the species* on cultivated plant targets by **affecting the cultivation system's integrity** is:

- **X** very low
- ☐ low
- ☐ medium
- ☐ high
- ☐ very high

| | | | | | |
|---|---|---|---|---|---|
| aconf18. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm22. Comments:

This species does not affect the cultivation of plants by disturbing their integrity.

**a23**. The effect of *the species* on cultivated plant targets by hosting **pathogens or parasites** that are harmful to them is:

- **X** very low
- ☐ low
- ☐ medium
- ☐ high
- ☐ very high

| | | | | | |
|---|---|---|---|---|---|
| aconf19. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm23. Comments:

There is no data that would indicate that *C. fluminea* could be a host or vector of pathogens and parasites harmful to plants.

## A4c | Impact on the domesticated animals domain

Questions from this module qualify the consequences of *the organism* on domesticated animals (e.g. production animals, companion animals). It deals with both the well-being of individual animals and the productivity of animal populations.

**a24**. The effect of *the species* on individual animal health or animal production, through **predation or parasitism** is:

| | |
|---|---|
| | inapplicable |
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf20. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm24. Comments:

*Corbicula fluminea* does not affect the health of a single animal or animal production through predation or parasitism.

**a25**. The effect of *the species* on individual animal health or animal production, by having properties that are hazardous upon **contact**, is:

| | |
|---|---|
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf21. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm25. Comments:

There is no data that would indicate that these clams can have an effect on the health of an individual animal or animal production by presenting properties that pose a danger during direct contact.

**a26**. The effect of *the species* on individual animal health or animal production, by hosting **pathogens or parasites** that are harmful to them, is:

| | |
|---|---|
| | inapplicable |
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf22. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm26. | Comments:<br>This clam does not carry parasites and pathogens harmful to livestock and farm animals. |

## A4d | Impact on the human domain

Questions from this module qualify the consequences of *the organism* on humans. It deals with human health, being defined as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (definition adopted from the World Health Organization).

**a27**. The effect of *the species* on human health through **parasitism** is:

| | |
|---|---|
| **X** | inapplicable |
| | very low |
| | low |
| | medium |
| | high |
| | vert high |

| | | | | | |
|---|---|---|---|---|---|
| aconf23. | Answer provided with a | low | medium | high | level of confidence |

| | |
|---|---|
| acomm27. | Comments:<br>The species is not a parasite. |

**a28**. The effect of *the species* on human health, by having properties that are hazardous upon **contact**, is:

| | |
|---|---|
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf24. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm28. | Comments:<br>Bivalve tissues secrete mucus which can be allergenic for some people as a result of direct contact (BHP UJ 2010 - P). *Corbicula fluminea* is an edible species (Chung et al. 2001 - P), but in Poland there is no tradition of eating bivalves. *Corbicula fluminea* can accumulate heavy metals and pesticides (Villar et al. 1999, Uno et al. 2001 - P), which consequently could lead to poisoning at higher trophic levels. The probability of the species' effect on human health is low (less than one case of contact per 100,000 people per year); small effect (medical consultations are rare, the disease does not cause absenteeism, there are no permanent disabilities, low stress level), therefore the effect should be assessed as very low. |

**a29**. The effect of *the species* on human health, by hosting **pathogens or parasites** that are harmful to humans, is:

| | |
|---|---|
| | inapplicable |
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf25. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm29. | Comments:<br>This species accumulates human intestinal parasites (protozoa) from the genus *Cryptosporidium* and *Giardia* in its tissues (Izumi et al. 2004 - P). *Cryptosporidium* has one host, so after entering the clam it is no longer a threat to humans (Grzeszczuk and Prokopowicz 1999 - P). The transfer of *Giardia* by this species to humans has not been demonstrated. |

## A4e | Impact on other domains

Questions from this module qualify the consequences of *the species* on targets not considered in modules A4a-d.

**a30**. The effect of *the species* on causing damage to **infrastructure** is:

| | |
|---|---|
| | very low |
| | low |
| | medium |
| **X** | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf26. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm30. | Comments:<br>In Poland, no harmful effect of *C. fluminea* on hydrotechnical devices has been demonstrated, yet in the USA, Belgium and France, this clam poses a threat to the operation of submerged devices, including waterworks (Lachner et al. 1970, Swinnen et al. 1998 - P). The occurrence of the species causes pipe clogging due to the fact that young individuals are not very mobile, they attach, reproduce and die causing shells to be deposited (Stańczykowska and Kołodziejczyk 2011 - P, GISD - 2015 B). High densities, e.g. in the USA, cause difficulties in the operation of hydroelectric power stations, water treatment stations, sand and gravel production industry, in the agriculture and irrigation sectors (GISD 2015 - B). In Europe, this type of impact is rather small, as reported by Rosa et al. with regard to Portugal (2011 - P). *Corbicula fluminea* shells can also pose a problem for companies trading in sand and river gravel – these raw materials are contaminated with clam shells (Darrigran 2002 - P). At high densities the effect of the species can be described as high, because it could be irreversible. High probability (over 100 events per 100,000 objects per year), medium effect (partly reversible), high impact. |

## A5a | Impact on ecosystem services

Questions from this module qualify the consequences of *the organism* on ecosystem services. Ecosystem services are classified according to the Common International Classification of Ecosystem Services, which also includes many examples (CICES Version 4.3). Note that the answers to these questions are not used in the calculation of the overall risk score (which deals with ecosystems in a different way), but can be considered when decisions are made about management of *the species*.

**a31**. The effect of *the species* on **provisioning services** is:

| | |
|---|---|
| | significantly negative |
| **X** | moderately negative |
| | neutral |
| | moderately positive |
| | significantly positive |

| | | | | | |
|---|---|---|---|---|---|
| aconf27. | Answer provided with a | low | medium<br>**X** | high | level of confidence |

acomm31. Comments:

No data for Poland. *Corbicula fluminea* is a filter feeder, it participates in the water selfpurification process (Villar et al. 1999, Uno et al. 2001 - P). Its effect is noted as significant in habitats where it is very numerous (Sousa et al. 2008 a - P). *Corbicula fluminea* is used as a bioindicator of polluted environments (Graczyk 2003 - P). This clam accumulates heavy metals and pesticides (Bell-McCaulou 1993, Oliveira et al. 2015 - P). This species accumulates human intestinal parasites (protozoa) from the genus *Cryptosporidium* and *Giardia* in its tissues (Izumi et al. 2004 - P). *Cryptosporidium* has one host, so after entering the clam it is no longer a threat to humans (Grzeszczuk and Prokopowicz 1999 - P). The transfer of *Giardia* through *C. fluminea* to humans has not been demonstrated.

In Poland, no harmful effect of *C. fluminea* on hydrotechnical devices has been demonstrated, yet this clam poses a potential threat to the operation of submerged devices, including waterworks (Lachner et al. 1970, Swinnen et al. 1998 - P), causing difficulties in the operation of industrial plants, the agricultural sector, and society.

**a32**. The effect of *the species* on **regulation and maintenance services** is:

| | |
|---|---|
| | significantly negative |
| **X** | moderately negative |
| | neutral |
| | moderately positive |
| | significantly positive |

| | | | | | |
|---|---|---|---|---|---|
| aconf28. | Answer provided with a | low | medium<br>**X** | high | level of confidence |

acomm32. Comments:

In Poland, this type of data is missing despite the fact that the species has been present in our country for 15 years, so far no massive presence has been found. Its effect could be assessed as moderately negative only in habitats where *C. fluminea* is very numerous (Sousa et al. 2008 a - P). It is a filter feeder, participates in the process of water selfpurification, circulation of chemical elements, sedimentation process (Sousa et al. 2008 a- P). The clams of this species can catch certain protozoa (*Cryptosporidium parvum* (causing cryptosporidiosis) and *Giardia lamblia* (causing giardiosis)) from the water environment, and accumulate them in their tissues (Graczyk et al. 2003 - P). These protozoa are dangerous for dogs, cats and ruminants, if they freely occur in water environment. Transmission of human parasites by this species has not been demonstrated.

*Corbicula fluminea* also feeds thanks to cilia located on the foot (pedal feeding) , which mainly affects the abiotic characteristics of the upper layer of the sediment, but also on the carbon circulation and the concentration of organic matter (Hakenkamp and Palmer 1999 - P). Through filtration and foot nutrition, *Corbicula* is an important link between the processes occurring in the water column and at the bottom of the water reservoir, because it uses organic substances from these two compartments of the water reservoir (Hakenkamp and Palmer 1999 - P). *Corbicula* can also release a large amount of inorganic nitrogen in the form of feces and pseudofeces (Asmus and Asmus 1991 - P) and stimulate the primary production of submerged plants and phytoplankton (Phelps 1994 - P). This clam is called an "ecosystem engineer". It transforms the surface of the bottom sediments by drilling. It reduces the availability of habitats and even crowds out native bivalve species (small pill clams and fingernail clams, as well as young *Unionidae* individuals are particularly vulnerable (Vaughn and Hakenkamp 2001 - P). It competes for food with other species living on the bottom of reservoirs and limits the food access for plankton-feeder animals. It can filter and digest *Unionidae* mussel spermatozoa, their glochidia and even young individuals just after metamorphosis (McMahon 1991, Strayer 1999 - P). The mass mortality of *C. fluminea* affects the quality of water (Strayer 1999 - P), but also as a consequence, empty shells can become a convenient place of life for the benthos fauna (Werner and Rothhaupt

| | |
|---|---|
| | 2007 - P). This species can physically change the aquatic environments, their structure and functioning and lead to a decrease in the density of native bivalves while increasing the density of snails, insects and crustaceans (Illari et al. 2012 - P). Assuming that the species will reach a higher number in Poland, its impact will be moderately negative. |

**a33**. The effect of *the species* on **cultural services** is:

| | |
|---|---|
| | significantly negative |
| | moderately negative |
| **X** | neutral |
| | moderately positive |
| | significantly positive |

| | | | | | |
|---|---|---|---|---|---|
| aconf29. | Answer provided with a | low | medium **X** | high | level of confidence |

| | |
|---|---|
| acomm33. | Comments:<br>There is no data that would indicate that this clam influences cultural services in our country. |

## A5b | Effect of climate change on the risk assessment of the negative impact of *the species*

Below, each of the Harmonia$^{+PL}$ modules is revisited under the premise of the future climate. The proposed time horizon is the mid-21st century. We suggest taking into account the reports of the Intergovernmental Panel on Climate Change. Specifically, the expected changes in atmospheric variables listed in its 2013 report on the physical science basis may be used for this purpose. The global temperature is expected to rise by 1 to 2°C by 2046-2065.

Note that the answers to these questions are not used in the calculation of the overall risk score, but can be but can be considered when decisions are made about management of *the species*.

**a34**. INTRODUCTION – Due to climate change, the probability for *the species* to overcome geographical barriers and – if applicable – subsequent barriers of captivity or cultivation in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf30. | Answer provided with a | low | medium **X** | high | level of confidence |

| | |
|---|---|
| acomm34. | Comments:<br>The probability that due to global warming the species would be introduced more often will not change. |

**a35**. ESTABLISHMENT – Due to climate change, the probability for *the species* to overcome barriers that have prevented its survival and reproduction in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| | not change |
| **X** | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf31. | Answer provided with a | low | medium **X** | high | level of confidence |

acomm35. Comments:

It seems that the current climate of Poland does not promote strong establishment of *C. fluminea* in the country, with the exception of the warm cooling waters discharged by power plants and sites that are under constant influence of these waters. The increase in temperature in winter has positive effect on the growth rate of this species individuals and increases its reproductive success (Weitere et al. 2009 - P). Along with global warming, as a result of higher survival of young individuals, there may be an increase in density in occupied habitats. *Corbicula fluminea* clams could reproduce outside the cooling waters and their reproductive cycle could be shortened. Therefore, it is assumed that climate warming may affect the increase in the spread of *C. fluminea* in Poland (Crespo et al. 2015 - P).

Currently, low temperatures are a factor limiting the occurrence and, at the same time, causing the highest mortality of individuals (French and Schloesser 1991 - P) mainly in combination with a decrease in water level (Werner and Rothhaupt 2008 - P). Extreme climatic and environmental conditions (such as floods and accompanying large loads of transferred mud, droughts, extreme temperatures, low oxygen content) can also affect mass mortality of clams (Ilarri et al. 2011, Sousa et al. 2012 - P). However, it should be noted that the weather extremes will also affect native species (Sousa et al. 2012 - P).

**a36**. SPREAD – Due to climate change, the probability for *the species* to overcome barriers that have prevented its spread in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| | not change |
| **X** | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf32. | Answer provided with a | low | medium **X** | high | level of confidence |

acomm36. Comments:

The species is characterized by large expansion capabilities in habitats beyond the natural range, so it should be assumed that if the climate does not cool down significantly, which would prevent its reproduction, the expansion of this species will continue. As the temperature of the waters would increase, *C. fluminea* clams could reproduce outside the cooling waters and their reproductive cycle could be shortened and repeated many times a year. Therefore, it is assumed that climate warming may affect the increase in the spread of *C. fluminea* in Poland (Crespo et al. 2015 - P). It is likely that the survival of larvae in warmer waters will increase.

**a37**. IMPACT ON THE ENVIRONMENTAL DOMAIN – Due to climate change, the consequences of *the species* on wild animals and plants, habitats and ecosystems in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| | not change |
| **X** | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf33. | Answer provided with a | low | medium **X** | high | level of confidence |

acomm37. Comments:

In case of global warming along with establishment in new habitats and increasing the population density in new areas, the effect of the species on animals and natural habitats is likely to increase moderately and *C. fluminea* will reproduce more frequently or (and) their

| | |
|---|---|
| | reproductive cycle will be shortened. Larval survival may also increase, which in turn could lead to an increase in the population size. There may be a strong competition with native species for resources (food, living space). |

**a38**. IMPACT ON THE CULTIVATED PLANTS DOMAIN – Due to climate change, the consequences of *the species* on cultivated plants and plant domain in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf34. | Answer provided with a | low | medium | high **X** | level of confidence |

| | |
|---|---|
| acomm38. | Comments:<br>The species is an aquatic animal and does not affect arable crops or plant production in Poland. It is unlikely that this situation will change as a result of climate change. |

**a39**. IMPACT ON THE DOMESTICATED ANIMALS DOMAIN – Due to climate change, the consequences of *the species* on domesticated animals and animal production in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf35. | Answer provided with a | low | medium | high **X** | level of confidence |

| | |
|---|---|
| acomm39. | Comments:<br>The species does not affect animal production in Poland. This situation is unlikely to change as a result of climate change. There is no such data for fish farming. |

**a40**. IMPACT ON THE HUMAN DOMAIN – Due to climate change, the consequences of *the species* on human in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf36. | Answer provided with a | low | medium **X** | high | level of confidence |

| | |
|---|---|
| acomm40. | Comments:<br>The species does not affect people in Poland. It is unlikely that this situation will change as a result of climate change, unless the clam will become a desirable delicacy in the food market in our country. |

**a41**. IMPACT ON OTHER DOMAINS – Due to climate change, the consequences of *the species* on other domains in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| | not change |

| | |
|---|---|
| X | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf37. | Answer provided with a | low | medium | high X | level of confidence |

acomm41. Comments:

With the global warming, the population of this species is likely to increase in the occupied habitats, which may cause major difficulties in the operation of water infrastructure facilities (clogging of hydrotechnical equipment, water pipes). Climate warming could affect, for example, the occurrence of multiple reproductive periods of clams and lead to an increase in the population size of this species. Consequently, *C. fluminea* could become an undesirable species in water reservoirs.

## Summary

| Module | Score | Confidence |
|---|---|---|
| Introduction (questions: a06-a08) | 1.00 | 1.00 |
| Establishment (questions: a09-a10) | 1.00 | 1.00 |
| Spread (questions: a11-a12) | 0.75 | 0.5 |
| Environmental impact (questions: a13-a18) | 0.25 | 0.92 |
| Cultivated plants impact (questions: a19-a23) | 0.00 | 1.00 |
| Domesticated animals impact (questions: a24-a26) | 0.00 | 1.00 |
| Human impact (questions: a27-a29) | 0.00 | 1.00 |
| Other impact (questions: a30) | 0.75 | 1.00 |
| Invasion (questions: a06-a12) | 0.92 | 0.83 |
| Impact (questions: a13-a30) | 0,75 | 0.98 |
| Overall risk score | 0,69 | |
| Category of invasiveness | moderately invasive alien species | |

## A6 | Comments

This assessment is based on information available at the time of its completion. It has to be taken into account. However, that biological invasions are, by definition, very dynamic and unpredictable. This unpredictability includes assessing the consequences of introductions of new alien species and detecting their negative impact. As a result, the assessment of the species may change in time. For this reason it is recommended that it regularly repeated.

acomm42. Comments:

*Corbicula fluminea* is one of the most important alien species found in the aquatic environment (Crespo et al. 2015 - P). The introduction of this clam in Poland was predicted (Serafiński et al. 2002 - P), which was documented shortly afterwards, with the description of the first site of presence (Domagała et al. 2004 - P). This clam is a species described beyond the borders of our country as a nuisance species and achieving high densities, as well as a species with high invasiveness and reproductive ability. These clams are mainly hermaphroditic (Morton 1977, 1982, 1983, 1986 - P) and capable of self-fertilization

(Kraemer and Galloway 1986 - P). Their reproductive cycle and development of larvae are short (King et al. 1986, Kraemer and Galloway 1986 - P) and can be repeated many times a year (Łabęcka 2009 - P). Depending on the environmental conditions, these clams may present various life strategies. They can be oviparous, ovoviviparous and viviparous. They incubate the offspring in demibranchs or produce a planktonic larva (Byrne et al. 2000, Korniushin and Glaubrecht 2003, Korniushin 2004, Glaubrecht et al. 2006, Łabęcka 2009 - P). Di-, tri- and tetraploid individuals (Komaru et al. 1997, Park et al. 2000, Qiu et al. 2001 - P), as well as androgenetic reproduction (Komaru et al. 1998, Ishibashi et al. 2003, Hedtke et al. 2008, Pigneur et al. 2011 - P) are common in this species. They also form cryptic hybrids with *C. fluminalis* (Pfenniger et al. 2002 - P). In Poland, *C. fluminea* belongs to the established species (result of the questionnaire for establishment = 1.00, questions: a09-a10). The species does not create as numerous populations in Poland as in southern Europe, which is why the result of the survey regarding impact on the natural environment (question a13-a18) was 0.25, even assuming that *C. fluminea* is present throughout area of Poland. The climate of Poland is moderately favorable for this species, however the Harmonia$^{+PL}$ methodology indicates to select answer „optimal conditions". There are optimal habitat conditions and result of the questionnaire for the invasion process = 0.92 (question a06-a12). Periods of winter frost combined with the formation of ice cover on natural reservoirs probably affect the mortality of clams. Nevertheless, research suggests that a part of the population will always survive and will be able to rebuild it (Müller and Baur 2011 - P). It is noteworthy that *C. fluminea* is hermaphroditic also in Poland (Łabęcka 2009 - P). Therefore, what is particularly dangerous, the population can be established or rebuilt by even a single individual. In our country, this clam has not been invasive and has not negatively affected native fauna and habitats. However, it has the potential and predisposition to show negative influence. In Poland, however, the species encounters certain limitations. Low temperatures are undoubtedly a limiting factor. In case of a species that has invasive species properties outside Poland, caution should be demonstrated (overall risk score of 0.69) and monitoring of population size in Poland is recommended in order to limit possible future negative effect on ecosystems and natural habitats (result: 0.25; questions a13-a18), and water infrastructure (effect on other objects = 0.75, question: a30). The foregoing assessment was influenced mainly by the main effect of these clams on the infrastructure of our western neighbors, which was taken into account in the risk assessment. Provided this clam would spread over entire area of our country, its effect could be large.

## Data sources

**1. Published results of scientific research (P)**


Aldridge DC, Müller SJ. 2001. The Asiatic clam, *Corbicula fluminea*, in Britain: current status and potential impacts. Journal of Conchology 37: 177

Asmus RM, Asmus H. 1991. Mussel beds: limiting or promoting phytoplankton? J. Exp. Mar. Biol. Ecol. 148: 215-232

Bell-McCaulou T.M. 1993 *Corbicula fluminea* as a bioindicator on the lower Colorado River. Master's thesis. University of Arizona, Tucson.

Beran L. 2000. First record of *Corbicula fluminea* (Mollusca: Bivalvia) in the Czech Republic. Acta Societatis Zoologicae Bohemicae 64 (1): 1-2

Bij de Vaate A. 1991. Colonization of the German part of the River Rhine by the Asiatic clam, *Corbicula fluminea* Müller, 1774 (Pelecypoda, Corbiculidae). Bulletin Zoölogisch Museum. Universiteit van Amsterdam 13(2): 13-16

Boltovskoy D, Izaguirre I, Correa N. 1995. Feeding selectivity of *Corbicula fluminea* (Bivalvia) on natural phytoplankton. Hydrobiologia 312: 171-182

Bonk M, Zając K, Lipińska A.M. 2018. Rapid expansion of the Asian clam *Corbicula fluminea* (O. F. Müller, 1774): a new alien species in the mollusk community of the Vistula. Oceanological and Hydrobiological Studies 47: DOI: 10.1515/ohs-2018-0000

Byrne M, Phelps H, Church T, Adair V, Selvakumaraswamy P, Potts J. 2000. Reproduction and development of the freshwater clam *Corbicula australis* in southeast Australia Hydrobiologia 418: 185-197

Cantanhede G, Hahn NS, Gubiani É.A, Fugi R. 2008. Invasive molluscs in the diet of *Pterodoras granulosus*(Valenciennes,1821) (Pisces, Doradidae) in the Upper Paraná River floodplain, Brazil Ecol. Freshw. Fish. 17: 47-53

Cebulska K, Krodkiewska M. 2017. The dispersion of *Corbicula fluminea* (O. F. Müller, 1774) (Mollusca: Corbiculidae) in the Upper Oder River (Southern Poland). 8th European Congress of Malacological Societes. Kraków, Polska 114-114

Chung PR, Jung Y, Park YK, Hwang MG, Soh CT. 2001. *Corbicula fluminea* (Bivalvia: Corbiculidae): a possible second molluscan intermediate host of Echinostoma cinetorchis (Trematoda: Echinostomatidae) in Korea. The Korean Journal of Parasitology 39 (4): 329-332

Ciutti F, Cappelletti C. 2009. First Record of *Corbicula fluminalis* (Müller, 1774) in Lake Garda (Italy), living in sympatry with *Corbicula fluminea* (Müller, 1774). Journal of Limnology 68(1): 162-165

Crespo D, Dolbeth M, Leston S, Sousa R, Pardal MÂ. 2015. Distribution of *Corbicula fluminea* (Müller, 1774) in the invaded range: a geographic approach with notes on species traits variability. Biological Invasions 17: 2087-2101

Darrigran G. 2002. Potential impact of filter-feeding invaders on temperate inland freshwater environments Biol. Invasions. 4: 145-156

Domagała J, Łabęcka MA, Pilecka-Rapacz M, Migdalska B. 2004. *Corbicula fluminea* (O.F. Müller, 1774) (Bivalvia, Corbiculidae) – a species new to the Polish malacofauna. Folia Malacologica 12: 145-148 DOI: 10.12657/ folmal.012.011.

Elliott P, Ermgassen PS. 2008. The Asian clam (*Corbicula fluminea*) in the River Thames, London, England. Aquatic Invasions 31: 54-60

Ferreira-Rodríguez N, Pardo I. 2016. An experimental approach to assess *Corbicula fluminea* (Müller, 1774) resistance to osmotic stress in estuarine habitats.Estuarine, Coastal and Shelf Science 176: 110-116

French JR, Schloesser DW. 1991. Growth and overwinter survival of the Asiatic clam, *Corbicula fluminea*, in the St. Clair River, Michigan. Hydrobiologia 219: 165-170

Glaubrecht M, Fehér Z, von Rintelen T. 2006. Brooding in *Corbicula madagascariensis* (Bivalvia, Corbiculidae) and the repeated evolution of viviparity in corbiculids. Zoologica Scripta35 (6): 641-654

Graczyk TK, Conn DB, Marcogliese DJ, Graczyk H, de Lafontaine Y. 2003. Accumulation of human waterborne parasites by zebra mussels (*Dreissena polymorpha*) and Asian freshwater clams (*Corbicula fluminea*). Parasitol Res. 89: 107-112

Grzeszczuk A, Prokopowicz D. 1999. *Cryptosporidium parvum* – współczesne zagrożenie człowieka. Przegląd Epidemiologiczny 53 (3-4): 345-353

Hakenkamp C, Palmer MA. 1999. Introduced bivalves in freshwater ecosystems: the impact of *Corbicula* on organic matter dynamics in a sandy stream. Oecologia 119: 445-451

Hedtke S, Stanger-Hall K, Baker RJ, Hillis DM. 2008. All-male asexuality: origin and maintenance of androgenesis in the asian clam *Corbicula*. Evolution 62-5: 1119-1136

Hubenov Z, Trichkova T, Kenderov L, Kozuharov D. 2013. Distribution of *Corbicula fluminea* (Mollusca: Corbiculidae) over an eleven-year period of its invasion in Bulgaria. Acta Zoologica Bulgarica 65: 315-326

Ilarri MI, Antunes C, Guilhermino L, Sousa R. 2011. Massive mortality of the Asian clam *Corbicula fluminea* in a highly invaded area. Biological Invasions 13: 277-280

Ilarri MI, Freitas F, Costa-Dias S, Antunes C, Guilhermino L, Sousa R. 2012. Associated macrozoobenthos with the invasive Asian clam *Corbicula fluminea*. Journal of Sea Research 72: 113-120

Ishibashi R, Ookubo K, Aoki M, Utaki M, Komaru A, Kawamura K. 2003. Androgenetic reproduction in a freshwater diploid clam *Corbicula fluminea* (Bivalvia: Corbiculidae). Zoological Science 20: 727-732

Izumi T, Itoh Y, Yagita K, Endo T, Ohyama T. 2004. Brackish water benthic shellfish (*Corbicula japonica*) as a biological indicator for *Cryptosporidium parvum* oocysts in river water. Bull Environ Contam Toxicol. 72(1): 29-37

Johnson PD, McMahon RF. 2011. Effects of temperature and chronic hypoxia on survivorship of the zebra mussel (*Dreissena polymorpha*) and Asian clam (*Corbicula fluminea*). Canadian Journal of Fisheries and Aquatic Sciences 55(7): 1564-1572

King CA, Langdon CJ, Counts III CL. 1986. Spawning and early development of *Corbicula fluminea* (Bivalvia: Corbiculidae) in laboratory culture. American Malacological Bulletin 4 (1): 81-88

Komaru A, Konishi K, Nakayama I, Kobayashi T, Sakai H, Kawamura K. 1997. Hermaphroditic freshwater clams in the genus *Corbicula produce* non-reductional spermatozoa with somatic DNA content. Biological Bulletin 193: 320-323

Komaru A, Kawagishi T, Konishi K. 1998. Cytological evidence of spontaneous androgenesis in the freshwater clam *Corbicula leana* Prime. Development Genes and Evolution 208: 46-50

Korniushin AV. 2004. A revision of some Asian and African freshwater clams assigned to *Corbicula fluminalis* (Müller, 1774) (Mollusca: Bivalvia: Corbiculidae), with review of anatomical characters and reproductive features based on museum collections. Hydrobiologia 529: 251-270

Korniushin AV, Glaubrecht M. 2003. Novel reproductive modes in freshwater clams: brooding and larval morphology in Southeast Asian taxa of *Corbicula* (Mollusca, Bivalvia, Corbiculidae). Acta Zoologica (Stokholm) 84: 293-315

Kraemer LR, Galloway ML. 1986. Larval development of *Corbicula fluminea* (Müller) (Bivalvia: Corbiculacea): an appraisal of its heterochrony. American Malacological Bulletin 41 (1): 61-79

Lachner EA, Robins CR, Courtenay WR.Jr.1970. Exotic fishes and other aquatic organisms introduced into North America. Smithsonian Contributions to Zoology 59: 1-29

Łabęcka AM. 2009. Cykl płciowy zawleczonych gatunków małży *Sinanodonta woodiana* (Lea, 1834), *Corbicula fluminea* (O.F. Müller, 1774) oraz *Corbicula fluminalis* (O.F. Müller, 1774) (Mollusca: Bivalvia) z kanału zrzutowego wód pochłodniczych Elektrowni Dolna Odra. In: Rozprawa doktorska, Uniwersytet Szczeciński, Szczecin. 1: 1-163

Maćkiewicz J. 2013. The first record of the Asian Clam *Corbicula fluminea* (Bivalvia: Veneroida: Corbiculidae) in the upper Vistula (South Poland). Folia Malacologica 21 (2): 87-90

Marchowski D, Jankowiak Ł, Wysocki D. 2016. Newly demonstrated foraging method of Herring Gulls and Mew Gulls with benthivorous diving ducks during the nonbreeding period. The Auk 133: 31-40

Mattice JS, Dye LL. 1976. Thermal tolerance of the adult Asiatic Clam. In: GW Esch, RW McFarlane (ed.). Thermal Ecology II, United States Energy Research and Development Association ERDA Symposium Series.130-135 Springfield, Virginia: National Technical Information Service.

McMahon RF. 1983. Ecology of an invasive pest bivalve, *Corbicula*.In: W.D. Russell-Hunter (eds.). The Mollusca. Ecology 505-561 Academic Press, New York

McMahon RF. 1991. Ecology and classification of North American freshwater invertebrates.In: J.H. Thorp, A.P. Covish (ed.). Mollusca: Bivalvia. 315-399 Academic Press, New York

McMahon RF. 2000. Invasive characteristics of the freshwater bivalve *Corbicula fluminea*. In: R. Claudi, J. Leach (ed.). Nonindigenous Freshwater Organisms: Vectors, Biology and Impacts. 315-34 Lewis Publishers, Boca Raton

McMahon RF. 2002. Evolutionary and physiological adaptations of aquatic invasive animals: r selection versus resistance. Can. J. Fish. Aquat. Sci. 59: 1235-1244

Minchin D. 2014. The distribution of the Asian clam *Corbicula fluminea* and its potential to spread in Ireland. Management of Biological Invasions 52: 165-177

Morton B. 1977. The population dynamics of *Corbicula fluminea* (Bivalvia: Corbiculacea) in Plover Cove Reservoir, Hong Kong (with erratum). Journal of Zoology, London 181: 21-42

Morton B. 1982. Some aspects of the population structure and sexual strategy of *Corbicula* cf. *fluminalis* (Bivalvia: Corbiculacea) from the Pearl River, Peoples Republic of China. Journal of Molluscan Studies 48: 1-23

Morton B. 1983. The sexuality of *Corbicula fluminea* (Müller) in lentic and lotic waters in Hong Kong. Journal of Molluscan Studies 49 (1): 81-83

Morton B. 1986. *Corbicula* in Asia – an updated synthesis. American Malacological Bulletin 2: 113-124

Müller O, Baur B. 2011. Survival of the invasive clam *Corbicula fluminea* (Müller) in response to winter water temperature. Malacologia 53(2): 367-371

Novais A, Souza AT, Ilarri M, Pascoal C, Sousa R. 2016. Effects of the invasive clam *Corbicula fluminea* (Müller, 1774) on an estuarine microbial community. Science of the Total Environment. 566: 1168-1175

Oliveira P, Lopes-Lima M, Machado J, Guilhermino L. 2015. Comparative sensitivity of European native (*Anodonta anatina*) and exotic (*Corbicula fluminea*) bivalves to mercury. Estuarine, Coastal and Shelf Science 167: 191-198

Park GM, Yong TS, Im KI, Chung EY. 2000. Karyotypes of three species of *Corbicula* (Bivalvia: Veneroida) in Korea. Journal of Shellfish Research 19 (2): 979-982

Pérez-Bote JL, Fernández J. 2008. First record of the Asian clam *Corbicula fluminea* (Müller, 1774) in the Guadiana River Basin (southwestern Iberian Peninsula). Aquatic Invasions 3: 87-90

Pfenninger M, Reinhardt F, Streit B. 2002. Evidence for cryptic hybridization between different evolutionary line ages of the invasive clam genus *Corbicula* (Veneroida, Bivalvia). Journal of Evolutionary Biology 15: 818-829

Phelps HL. 1994. The Asiatic clam (*Corbicula fluminea*) invasion and system-level ecological change in the Potomac River Estuary near Washington, D.C. Estuaries 17: 614-621

Piechocki A, Szlauer-Łukaszewska A. 2013. Molluscs of the middle and lower Odra: the role of the river in the expansion of alien species in Poland. Folia Malacologica 21: 73-86

Pigneur LM, Marescaux J, Roland K, Etoundi E, Descy JP, Van Doninck K. 2011. Phylogeny and androgenesis in the invasive *Corbicula clams* (Bivalvia, Corbiculidae) in Western Europe. Evolutionary Biology 11: 147

Prezant RS, Chalermwat K. 1984. Flotation of the bivalve *Corbicula fluminea* as a means of dispersal. Science 225: 1491-1493

Qiu A, Shi A, Komaru A. 2001. Yellow and brown color morphs of *Corbicula fluminea* (Bivalvia: Corbiculidae) from Sichuan Province, China, are triploids and tetraploids. Journal of Shellfish Research 20 (1): 323-328

Romanowski J, Winczek M, Ceryngier P. 2016. Stwierdzenie *Corbicula fluminea* (O. F. Müller, 1774) (Veneroida: Corbiculidae) w Wiśle w Warszawie. Kulon 21: 131-133

Rosa IC, Pereira JL, Gomes J, Saraiva PM, Gonçalves F, Costa R. 2011. The Asian clam *Corbicula fluminea* in the European freshwater-dependent industry: A latent threat or a friendly enemy? Ecological Economics 70: 1805-1813

Schmidlin S, Schmera D, Ursenbacher S, Baur B. 2012. Separate introductions but lack of genetic variability in the invasive clam *Corbicula* spp. in Swiss lakes. Aquatic invasions 7 (1): 73-80

Serafiński W, Krodkiewska M, Strzelec M. 2002. Czy azjatycki małż *Corbicula fluminea* (Müller) zagraża słodkowodnym środowiskom w Polsce? Przegląd Zoologiczny XLVI (1-2): 19-26

Sousa R, Antunes C, Guilhermino L. 2007. Species composition and monthly variation of the Molluscan fauna in the freshwater subtidal area of the River Minhoestuary.S.Estuar. Coast. Shelf. 75: 90-100

Sousa R, Antunes C, Guilhermino L. 2008 a. Ecology of the invasive Asian clam *Corbicula fluminea* (Müller, 1774) in aquatic ecosystems: an overview. Annales de Limnologie-International Journal of Limnology 44: 85-94

Sousa R, Rufino M, Gaspar M, Antunes C, Guilhermino L. 2008 b. Abiotic impacts on spatial and temporal distribution of *Corbicula fluminea* (Müller, 1774) in the river Minho Estuary, Portugal. Aquatic Conservation: Marine And Freshwater Ecosystems 18: 98-110

Sousa R, Varandas S, Cortes R, Teixeira A, Lopes-Lima M, Machado J, Guilhermino L. 2012. Massive die-offs of freshwater bivalves as resource pulses. Annales de Limnologie – International Journal of Limnology 48: 105-112

Stańczykowska A, Kołodziejczyk A. 2011. *Corbicula fluminea* (O. F. Müller, 1774)W: Głowaciński Z., Okarma H., Pawłowski J., Solarz W. (red.). Gatunki obce w faunie Polski. 151-156 Wyd. Inst. Ochr. Przyr. PAN, Kraków

Strayer DL. 1999. Effects of alien species on freshwater molluscs in North America. J. N. Am. Benthol. Soc. 74-98: 18

Swinnen F, Leynen M, Sablon R, Duvivier L, Vanmaele R. 1998. The Asiatic clam *Corbicula* (Bivalvia: Corbiculidae) in Belgium. Bulletin de l'Instut Royal Des Scienses Naturelles de Belgique. Sciences de la Terre Biologie 68: 47-53

Tittizer T, Taxacher M. 1997. Erstnachweis von *Corbicula fluminea*/*fluminalis* (Müller 1774) (Corbiculidae, Mollusca) in der Donau. Lauterbornia 31: 103-107

Uno S, Shiraishi H, Hatakeyama S, Otsuki A, Koyama J. 2001. Accumulative characteristics of pesticide in organs of bivalves (*Anodonta woodiana* and *Corbicula fluminea*) under natural conditions. Arch. Inviron. Toxicol. 40: 35-47

Vaughn CC, Hakenkamp CC. 2001. The functional role of burrowing bivalves in freshwater ecosystems. Freshwater Biology 46: 1431-1446

Villar C, Stripeikis J, D'Huicque L, Tudion M, Troccoli O, Bonetto C. 1999. Cd, Cu, Zn concentrations in sediments and the invasive bivalves Limnoperna fortunei and *Corbicula fluminea* at the Río de la Plata basin, Argentina. Hydrobiologia 416: 41-49

Vrabec V, Čejka T, Šporka F, Hamerlík L, Král D. 2003. First records of *Corbicula fluminea* (Mollusca, Bivalvia) from Slovakia with a note about its dispersion in Central Europe. Biologia Bratislava 58 (5): 942-952

Wawrzyniak-Wydrowska B. 2007. Preliminary studies on the occurence of the Asiatic clam *Corbicula fluminea* (O.F. Müller, 1774) (Bivalvia: Corbiculidae) in River Odra (Poland). W: World Congress of Malacology. Antwerpia, Belgia .238-239

Weitere M, Vohmann A, Schulz N, Linn C, Dietrich D, Arndt H. 2009. Linking environmental warming to the fitness of the invasive clam *Corbicula fluminea*.Global Change Biology 15: 2838-2851

Werner S, Rothhaupt KO. 2007. Effects of the invasive bivalve *Corbicula fluminea* on settling juveniles and other benthic taxa.J. N. Am. Benthol. Soc. 26 (4): 673-680

Werner S, Rothhaupt KO. 2008. Mass mortality of the invasive bivalve *Corbicula fluminea* induced by a severe low-water event and associated low water temperatures. Hydrobiologia 613: 143-150

**2. Databases (B)**

GISD GLOBAL INVASIVE SPECIES DATABASE(GISD). 2015. Species profile *Corbicula fluminea*. (http://www.iucngisd.org/gisd/species.php?sc=537) Access: 2018-01-31

**3. Unpublished data (N)**

**–**

**4. Other (I)**

Allegro. 2018. Mini małż – żywy filtr do akwarium (http://allegro.pl/mini-malza-zywy-filtr-do-akwa-ladne-hit-saxon4-i6737600939.html?reco_id=8653c73c-0614-11e8-9935-246e9677f9f8&bi_c=Product&bi_m=reco&bi_s=archiwum_allegro) Access: 2018-01-31

BHP UJ. 2010. Zalecenia BHP Uniwersytetu Jagiellońskiego

Piechocki A. 2004. Informacja ustna

**5. Author's own data (A)**

Łabęcka AM. 2004-2010. Obserwacje własne dot. oferowania do sprzedaży "Corbicula javanicus" na portalach internetowych

Łabęcka AM. 2005-2007. Badania własne nieopublikowane